DOCUMENT RESUME

ED 062 184	24	SE 013 666

AUTHOR	Kratochvil, Daniel W.
TITLE	Arithmetic Proficiency Training Program Developed by Science Research Associates, Inc. Product Development Report No. 11.
INSTITUTION	American Institutes for Research in the Behavioral Sciences, Palo Alto, Calif.
SPONS AGENCY	Office of Program Planning and Evaluation (DHEW/OE), Washington, D.C.
REPORT NO	AIR-21900-1-72-11
PUB DATE	Jan 72
CONTRACT	OEC-0-70-4892
NOTE	50p.
EDRS PRICE	MF-$0.65 HC-$3.29
DESCRIPTORS	Arithmetic; Basic Skills; *Computer Assisted Instruction; *Curriculum Development; Educational Equipment; Educational Innovation; *Elementary School Mathematics; *Evaluation; Marketing; Programing Languages

ABSTRACT

This report summarizes the development of a commercially available program in computational skills which makes extensive use of computer capabilities. The first section describes the organization, content, and cost of the materials, and the procedures for using them. The key personnel, and the organizational and funding sources are then named. Three phases in the development process are next identified: (1) informal tryouts, (2) program development using the APL/360 programming language, and (3) conversion to Coursewriter III language. Formative evaluation during the second phase and summative evaluation after the third phase are described in some detail. Final sections of the report outline the marketing procedures for the product, its degree of adoption, possible future developments, and four crucial decisions in its developmental history. (MM)

OE-PPE
SE

PRODUCT DEVELOPMENT REPORT NO. 11

ARITHMETIC PROFICIENCY TRAINING PROGRAM

DEVELOPED BY SCIENCE RESEARCH ASSOCIATES, INC.

January, 1972

Contract No. OEC-0-70-4892

AMERICAN INSTITUTES FOR RESEARCH
Post Office Box 1113 / Palo Alto, California 94302

AIR-21900-1/72-TR(11)

PRODUCT DEVELOPMENT REPORT NO. 11

Contract No. OEC-0-70-4892

ARITHMETIC PROFICIENCY TRAINING PROGRAM

DEVELOPED BY SCIENCE RESEARCH ASSOCIATES, INC.

Daniel W. Kratochvil

American Institutes for Research
in the Behavioral Sciences

Palo Alto, California

January, 1972

The research reported herein was performed pursuant to a contract with the Office of Education, U.S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
Office of Program Planning and Evaluation

PREFACE

This product development report is one of 21 such reports, each dealing with the developmental history of a recent educational product. A list of the 21 products, and the agencies responsible for their development, is contained in Appendix A to this report. The study, of which this report is a component, was supported by U.S. Office of Education Contract No. OEC-0-70-4892, entitled "The Evaluation of the Impact of Educational Research and Development Products." The overall project was designed to examine the process of development of "successful educational products."

This report represents a relatively unique attempt to document what occurred in the development of a recent educational product that appears to have potential impact. The report is based upon published materials, documents in the files of the developing agency, and interviews with staff who were involved in the development of the product. A draft of each study was reviewed by the developer's staff. Generally, their suggestions for revisions were incorporated into the text; however, complete responsibility for interpretations concerning any facet of development, evaluation, and diffusion rests with the authors of this report.

Although awareness of the full impact of the study requires reading both the individual product development reports and the separate final report, each study may be read individually. For a quick overview of essential events in the product history, the reader is referred to those sections of the report containing the flow chart and the critical decision record.

The final report contains: a complete discussion of the procedures and the selection criteria used to identify exemplary educational products; generalizations drawn from the 21 product development case studies; a comparison of these generalizations with hypotheses currently existing in the literature regarding the processes of innovation and change; and the identification of some proposed data sources through which the U.S. Office of Education could monitor the impact of developing products. The final report also includes a detailed outline of the search procedures and the information sought for each case report.

Permanent project staff consisted of Calvin E. Wright, Principal Investigator; Jack J. Crawford, Project Director; Daniel W. Kratochvil, Research Scientist; and Carolyn A. Morrow, Administrative Assistant. In addition, other staff who assisted in the preparation of individual product reports are identified on the appropriate title pages. The Project Monitor was Dr. Alice Y. Scates of the USOE Office of Program Planning and Evaluation.

Sincere gratitude is extended to those overburdened staff members of the 21 product development studies who courteously and freely gave their time so that we might present a detailed and relatively accurate picture of the events in the development of some exemplary educational research and development products. If we have chronicled a just and moderately complete account of the birth of these products and the hard work that spawned them, credit lies with those staff members of each product development team who ransacked memory and files to recreate history.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

PRODUCT DESCRIPTION

Product Characteristics

Name

The Arithmetic Proficiency Training Program (APTP).

Developer

Science Research Associates, Inc., a wholly owned subsidiary of IBM.

Distributor

Science Research Associates, Inc.

Focus

The Arithmetic Proficiency Training Program is a computer-assisted instructional program for supplementary use in the development of the computational skills of elementary arithmetic. It can be used with any elementary mathematics program--traditional, transitional, or modern.

Grade Level

The Arithmetic Proficiency Training Program is designed for grades one through eight and can be used remedially at any older age as well.

Target Population

The target population of APTP consists of all students in need of additional proficiency in computational skills.

Rationale for Product

Long Range Goals of Product

The long range goal of APTP is to individualize the learning of computational skills by students. By helping students master such skills through drill and practice and at their own level and their own rate, APTP is designed to free the teacher from the supervision of practice so that he can develop concepts, present ideas, and facilitate the student's understanding of arithmetic. Due to the ease of revision and expansion of a computer program (as contrasted with the difficulty and cost of revising a textbook series), the developers plan on-going improvement and enlargement of the program on the basis of feedback from user schools and of new ideas to be built in.

Objectives of Product

The objectives of APTP are:

1. To help the student achieve mastery of the computational skills customarily introduced in grades 1-6.

2. To provide the student personalized practice after individualized diagnosis has shown where practice is most appropriate.

3. To develop the student's speed and accuracy in computing, through sequences of timed practice problems.

The computational skills cover five areas and include 29 skills called molecules. In turn, each molecule is analyzed into a number of subskills called atomic skills. The atomic skills, which are very specific (e.g., finding the sum of four one-digit numbers where the sum is greater than or equal to 20), are organized in hierarchies. Each atomic skill with its associated mastery criteria constitutes a behavioral objective.

Philosophy and Theories Supporting Product

With regard to mathematics education, a fundamental assumption of APTP is that the student "must be able to do things, not just understand them." That is, to be fully competent in arithmetic, the student must have computational skills as well as an understanding of basic arithmetic concepts. Thus, students need practice in making computations. However, this practice should be individualized.

Individualization means that the student should work at his own level and at his own pace and that he should receive however much practice he needs and only that much. To accomplish the task of finding each student's appropriate level requires testing and, more specifically, diagnostic testing. Diagnostic testing is accomplished in the program by use of Gagné-type skill analyses and hierarchies. If a student cannot meet mastery criteria on a particular skill, the program searches through the prerequisite skills in the hierarchy until it locates some skill where the student cannot meet criteria but for which he has demonstrated mastery on the immediately prerequisite skills. At this point, the program shifts from its test mode into the practice mode and the student receives however many practice problems he needs to meet criteria.

There is considerable influence of Skinnerian ideas clearly visible in the program: reinforcement by immediate feedback is considered an essential

feature of the program; progress through very small steps is also an important feature; creating a situation where each student will experience success at his level is also important.

Description of Materials

Organization and Format of Materials

Physically, the Arithmetic Proficiency Training Program consists of two computer tapes and a variety of supporting guides and manuals. These are divided into a set of licensed materials (available only as a package leased by SRA to the user) and a set of unlicensed materials, which may be purchased separately. The licensed materials include the Basic Tape (consisting of the Coursewriter III statements and the Assembly Language functions needed to actually run the program on a computer), the Optional Tape (source card images, assembly listings, and flow charts), and the various operating instructions (Application Directory, Systems Manual, and Operator's Manual). These last three provide instructions to personnel operating the computer, so that they may understand the inner workings of the computer program.

The unlicensed materials include the Teacher's Guide, the Proctor's Guide, and the Student Record Book. These are the materials of concern to people in the school. The Teacher's Guide describes the program and its rationale, gives all the molecular skill maps (such as the one in Figure 1 on page 6) and detailed specifications of all the atomic skills (together with the "standard" settings for mastery speeds and block sizes), describes the several options for use of the program, and generally informs the teacher about how to use the program. The Proctor's Guide gives very specific and detailed instructions to the proctor, who is assumed to be a paraprofessional and whose functions include loading paper into the terminals, changing typewriter ribbons, helping students with the operation of the keyboard, etc. The Student Record Book consists of skill maps of each molecule; it provides the student with a graphic guide to the molecules so that he can keep track of his progress.

Content of Materials

The Basic computer tape for the Arithmetic Proficiency Training Program consists of (1) basic files of computational algorithms and the number generators which provide the desired numbers in the problems; and (2) the computer

instructions for processing the test and practice interactions of the student as well as making both momentary and cumulative reports of these interactions.

Educationally, the material is divided into the following 29 molecules which can be grouped into the five indicated groups.

Operations on Whole Numbers

Addition of Whole Numbers
Subtraction of Whole Numbers
Multiplication of Whole Numbers
Division of Whole Numbers

Operations on Fractions

Fractions--Lowest Terms
Multiplication of Fractions
Division of Fractions
Fractions--Higher Terms
Fractions--Common Denominator
Addition of Fractions
Subtraction of Fractions
Comparison of Fractions

Operations on Decimals

Addition of Decimals
Subtraction of Decimals
Multiplication of Decimals
Division of Decimals
Conversion of Decimals to Fractions
Conversion of Fractions to Decimals

Operations of Mixed Numbers

Conversion of Fractions to Mixed Numbers or Whole Numbers
Addition of Mixed Numbers
Conversion of Whole Numbers and Mixed Numbers to Fractions
Subtraction of Mixed Numbers
Multiplication of Mixed Numbers
Division of Mixed Numbers

Operations on Percents

Conversion of Decimals and Fractions to Percents
Conversion of Percents to Decimals and Fractions
Finding Percentage from Rate and Base
Finding Rate from Base and Percentage
Finding Base from Rate and Percentage

Each molecule (e.g., Finding Base from Rate and Percentage) is a complete program in itself and has been minutely subdivided into smaller skills called atomic skills. An atomic skill represents one idea or one shade of complexity in the molecular operation. For example, adding three one-digit numbers with a sum less than ten is a different and less advanced atomic skill than adding three one-digit numbers with a sum greater than or equal to ten. For each molecule, the atomic skills are arranged in a learning hierarchy. This hierarchy, or interrelationship between atomic skills, is shown in a skill map, such as the one in Figure 1 on the following page, for the addition of whole numbers. Each circle indicates an atomic skill and each arrow from one skill to another shows that mastery of the first skill is prerequisite to mastery of the second.

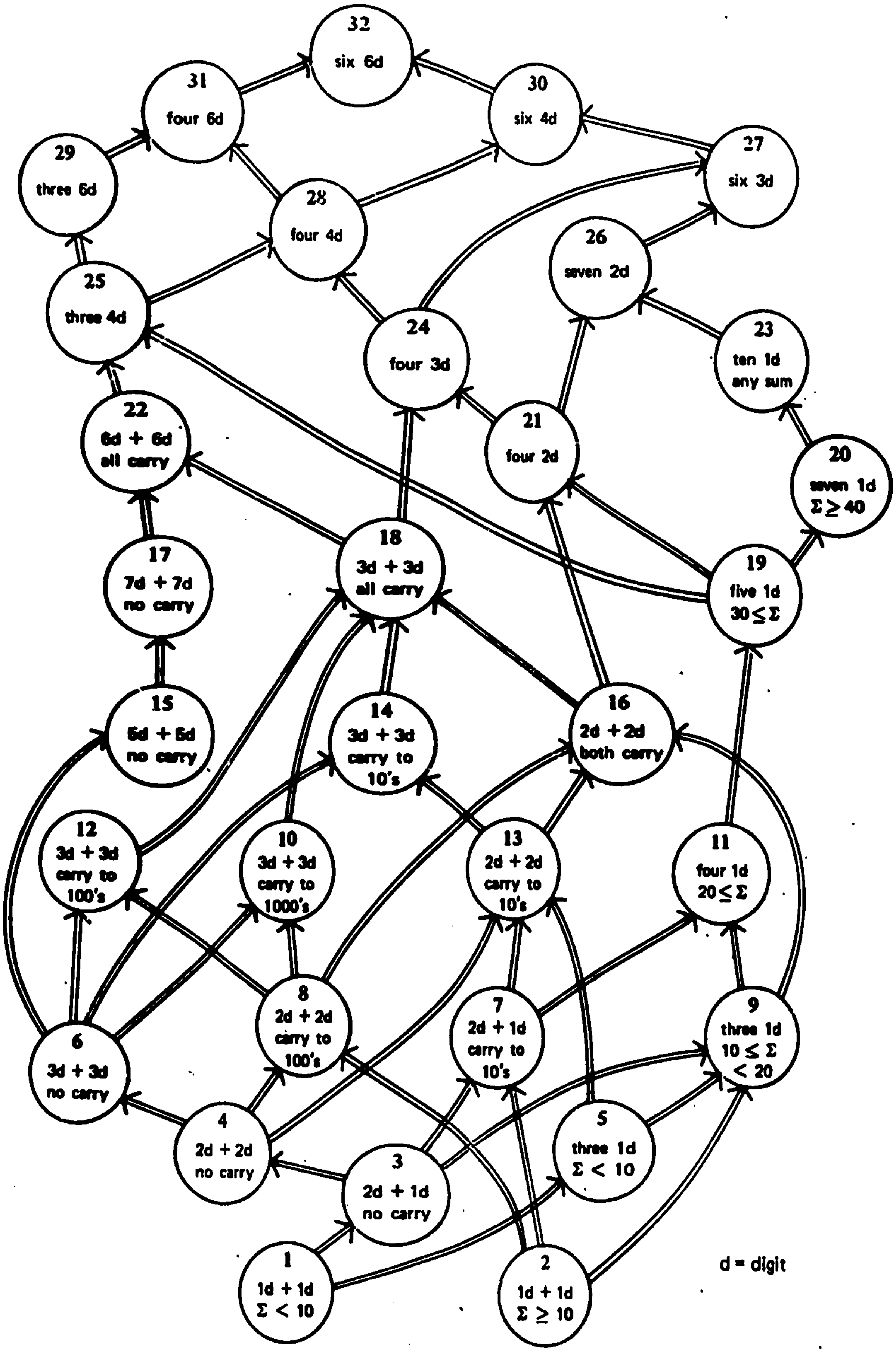
The program consists of 409 atomic skills like the 32 shown in Figure 1. Associated with each of these 409 atomic skills is a "block size" which, among other things, determines the minimum number of practice problems necessary to meet the mastery criteria; as problems increase in complexity, the block size decreases. For example, with the "standard" setting of 80% accuracy in the practice mode, the student must get four out of five problems right in Skill 32 of addition of whole numbers but must get 16 out of 20 right in the much simpler Skill 3, in order to meet criteria. With the minor exception of a few skills, the problems are "randomly" generated or selected by the computer program, within the very tight constraints of the skill specifications. This programming technique has the virtue of making available a very large number of different problems without the labor of writing these problems "by hand." The second level of programming turns the student's interaction with the areas and skills into a learning experience based upon placement and practice functions, with immediate feedback on accuracy and speed. This level of programming is discussed more extensively below, under Learner Activities.

Cost of Materials to User

APTP is licensed by SRA to customers at an annual use charge of $9,000. Payment of this charge entitles the customer to use the computer program on one central processing unit. An installation and training service by SRA is provided for an additional fee, at the customer's option.

Included in this $9,000 are licensed materials (i.e., tapes and instructions) and five copies each of the unlicensed materials (i.e., Teacher's Guide,

Figure 1. Skills Map for Addition of Whole Numbers



Proctor's Guide and Student Record). Additional copies of the unlicensed materials are available at the following prices:

	List	Net
Teacher's Guide	$10.00	$7.50
Proctor's Guide	6.67	5.00
Student Record	1.00	.75

The above prices are based on SRA's 1971 catalog and are subject to change.

Procedures for Using Product

Learner Activities

In APTP, the student works at a computer terminal that is similar to an electric typewriter. Examples of the interaction between the student and the computer program are shown in Figure 2 on the following two pages. The arrow in the left margin (which would not ordinarily be printed) indicates the typing done by the student; the rest is printed by the computer. The student spends about 20 minutes a day, or whatever length of time is considered appropriate, at the terminal, through which he communicates with the computer program. The student is first introduced to the APTP program by the teacher who gives him an overview of the program, the keyboard training, the computer, the role of the proctor, and her role as the teacher.

The initial segment in the program is designed to teach the student how to use the terminal. Like all other parts of APTP, this one is a dialogue between the student and the computer program. After every response the student makes, he receives a reply telling him how well he did (i.e., his accuracy and speed). While at the terminal, the student is led through exercises in typing numbers and performing several keyboard functions. He is recycled through these exercises until he has mastered the skills. Then he is allowed to begin his first arithmetic molecule.

The student's work on each arithmetic molecule is divided into two phases--placement and development. The placement phase is designed to determine the student's current level of ability in a molecule, while the development phase is designed to take him from his current level to mastery of the most difficult skill at the top of the molecule. In the placement phase, the student begins with a test in the middle of a molecule and moves up or down in

Figure 2. Examples of the interaction between the student and the computer

****
SKILL NUMBER 5 - TEST

SAMPLE PROBLEM:

$$\frac{19}{3} + \frac{23}{3} = ?$$

14/1

MASTERY SPEED: 7 SECONDS.

****

$$\frac{5}{3} + \frac{4}{3} = ?$$

→ 9/6

No. That's not right.

****

$$\frac{29}{3} + \frac{19}{3} = ?$$

→ 38/3

No. That's not right.

****

You have not mastered this skill yet.

****

****
SKILL NUMBER 5 - PRACTICE

SAMPLE PROBLEM:

$\frac{16}{3} + \frac{26}{3} = ?$

14/1

MASTERY SPEED: 7 SECONDS.
****

$\frac{19}{3} + \frac{26}{3} = ?$

→ 35/3

No. That's not right.

19 + 26 = ?

→ 45

OK. Now try the original problem.

$\frac{19}{3} + \frac{26}{3} = ?$

→ 45/3

Yes. But your answer must be reduced to lowest terms.

$\frac{19}{3} + \frac{26}{3} = ?$

→ 15/1

Right, but too slow.

****

$\frac{8}{3} + \frac{19}{3} = ?$

→ 9/1

Right, but too slow.
(17 seconds)

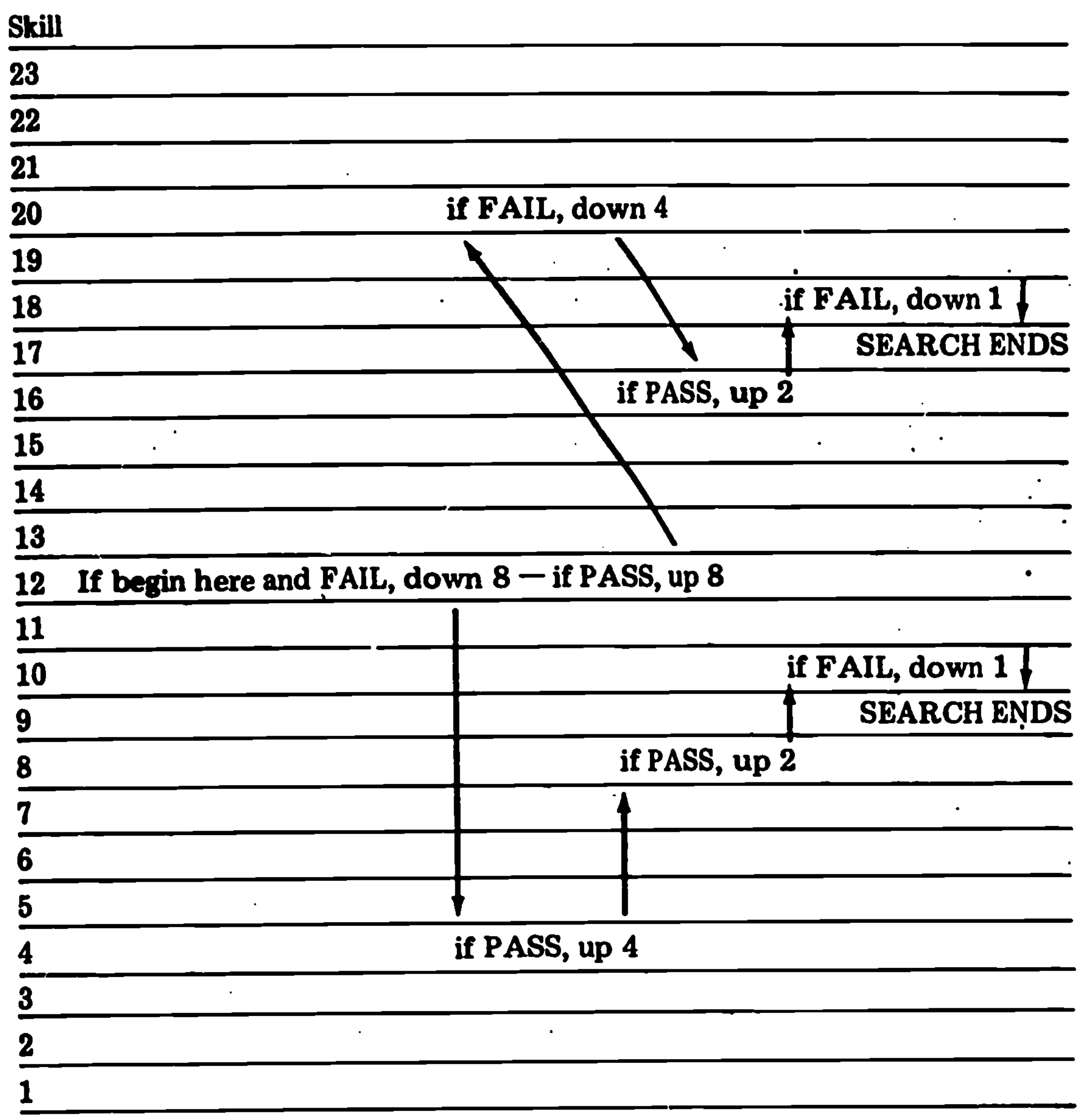
****

$\frac{26}{3} + \frac{7}{3} = ?$

→ 11
PERFECT!
(5 seconds)
****

successively smaller steps to other tests on atomic skills until he arrives at his appropriate level. The direction in which the student moves from test to test depends on whether he passes or fails. To pass a test for an atomic skill, he must answer 80% of the problems correctly and within the mastery speed specified for the atomic skill. Sample placement sequences for two students in the subtraction molecule have been traced in Figure 3 below. Each student took four tests; one found his level at atomic skill 9 and the other at 17.

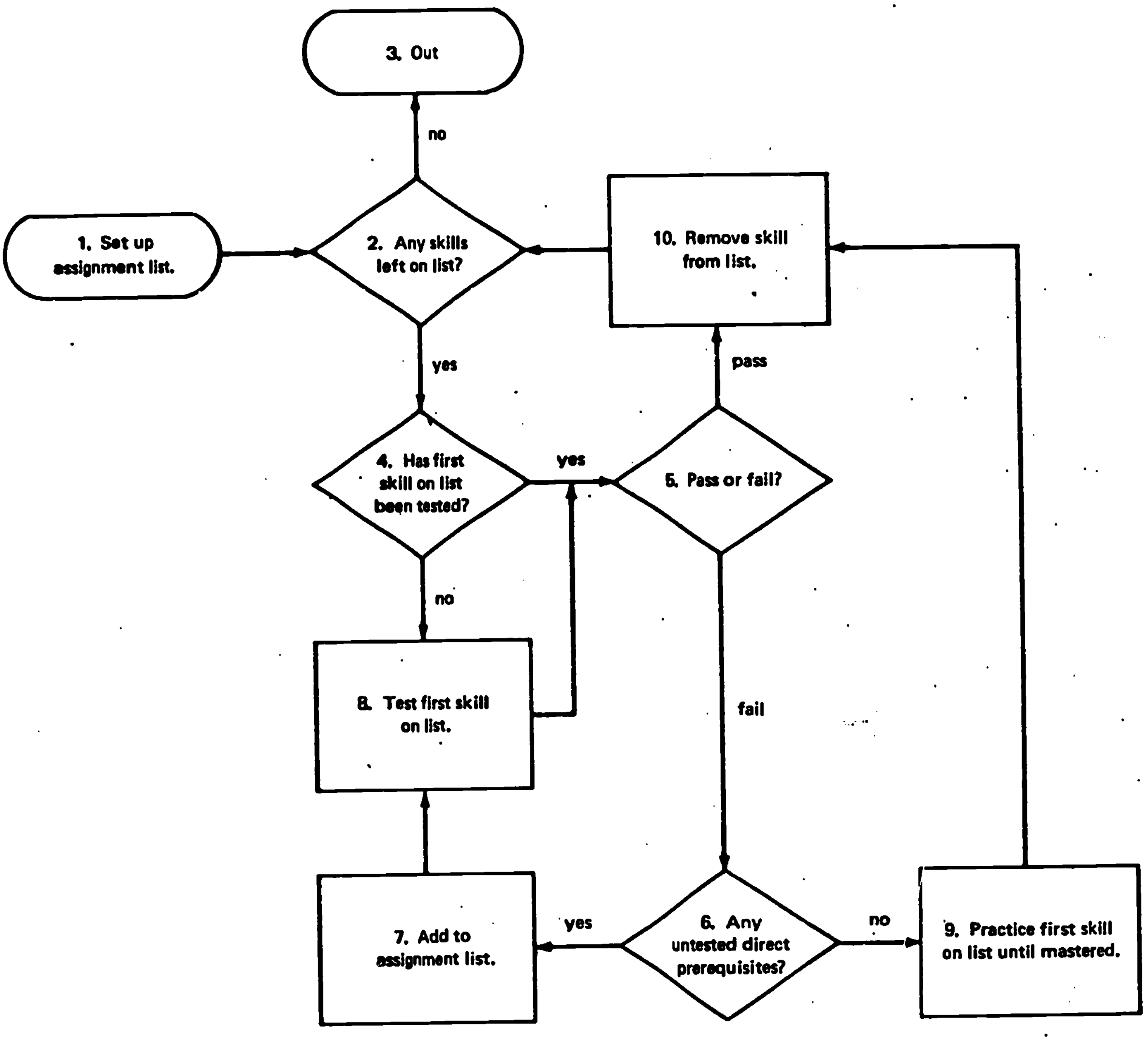
Figure 3. Sample Placement Sequence



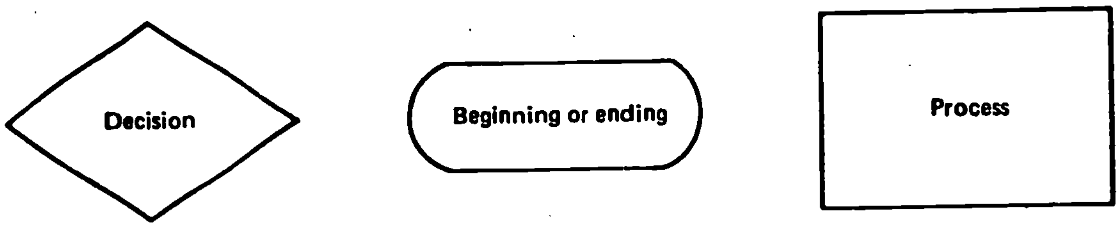
The student enters the developmental phase of the molecule after he has finished the last test in the placement phase. A flow chart of the steps in the developmental phase appears in Figure 4. A tentative list of skills, which includes the skills from the student's placement level to the top of the molecule and that the student must master to complete the molecule, is set up for the student (step 1). If the student passed the highest skill during placement, there would be no skills on the list (step 2) and he would be sent on to the next molecule (step 3). Next, the program determines if the student has been tested on the first skill on the list (step 4) and whether he passed or failed it (step 5). If he failed, a prerequisite testing system locates deficiencies related to the failed skill and adds these to his list of skills (step 7). Steps 5, 6, 7, and 8 are repeated until the program finds a skill that the student has failed but that has prerequisites that he can pass, or until there are no more direct prerequisites in the molecule. Then the student is given practice in the skills that he has not mastered, starting with the one lowest in the hierarchy (step 9). Practice problems are presented to the student in blocks of varying length, depending on the complexity of the atomic skill. The student is cycled through these blocks until he has mastered one. When he has, the program removes the atomic skill from the student's list (step 2), sends the student out of the molecule if there are not any left (step 3), or begins the cycle again (step 4), if there are some left.

What has been described are the typical student activities under the basic "X" option of operation. Additionally, there are three other options for use of the program. Under the "M" option, the teacher has greater flexibility in determining the course of the student's experience with APTP, in that she may make adjustments of such parameters as mastery speed, block size, and accuracy criteria. Under the "S" option, the teacher is allowed to select any of the 29 molecules, any one of the atomic skills in that molecule, and to specify either test or practice mode; no opportunity for adjustments of parameters occurs in this option, as it does in the "M" option. In the spiral curriculum option, the student follows a spiral curriculum of the teacher's choice through any or all of the 29 arithmetic molecules of the program. This option is illustrated by the example in Figure 5. The spiral in Figure 5 is one in which the student would first demonstrate mastery of low-level skills in Addition of Whole Numbers, would then go on to low-level skills in Subtraction

Figure 4. Diagram of Steps in Developmental Phase



'Key to symbol shapes:'



of Whole Numbers, and then to low-level skills in Multiplication of Whole Numbers. This would constitute "Orbit A" of the spiral. Then, the student continues on to Orbit B where he successively demonstrates mastery of the next higher level of skills in Addition, in Subtraction, and in Multiplication and low-level skills in Division of Whole Numbers. The student then goes on to Orbit C. This does not require any teacher intervention. This option is claimed to be especially effective in developmental use of the program with children in the early grades, as contrasted to remedial use with older students.

When a student completes a session at the terminal, a record of his performance for the session is printed out. This provides the student with an overview of his progress for that day. To keep a cumulative record of his progress, the student keeps track of his progress in the APTP Student Record Book by checking off completed skills that are mapped for each molecule in the book.

Teacher Activities

The teacher registers the student in the APTP program; introduces him to the program; controls, if she chooses, some features of the developmental phase; responds to the student when the program generates a "teacher call"; and discusses with the student his daily progress. The caretaking of the machines and records is delegated to a proctor who can be any responsible adult (e.g., a teaching assistant, a parent or a college student).

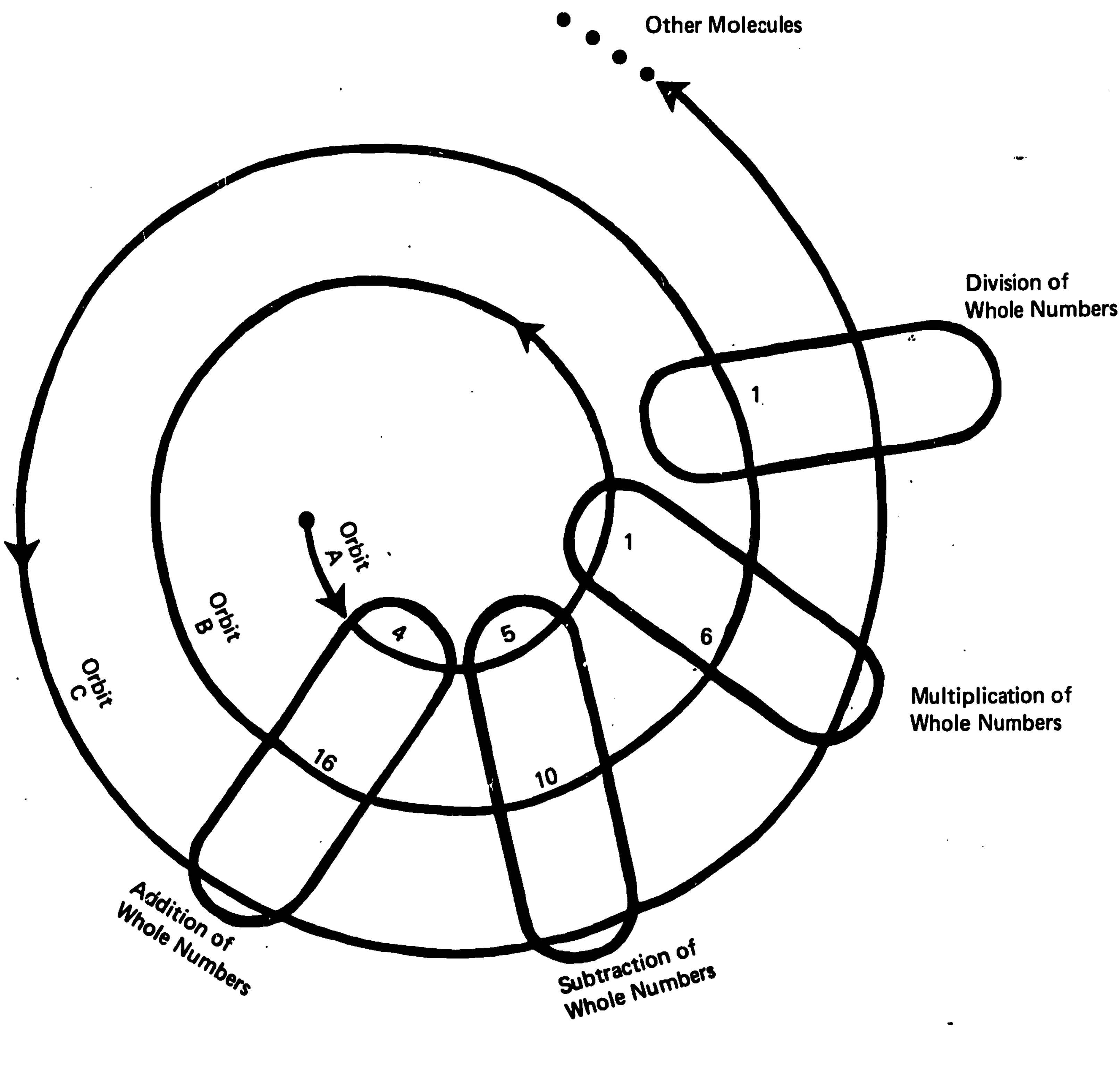
When introducing the student to the program, the teacher needs to explain the purpose of the program and the student's role in it, as well as her own role in it. The Teacher's Guide provides information pertaining to this teacher activity as well as information on the other teacher activities. The teacher might choose to control some of the features of the developmental phase instead of having the program operate them. She can:

1. List the atomic skills the student should use in a molecule.

2. Specify test or practice mode for any atomic skill.

3. Alter the block size, the mastery speed, or the accuracy criteria.

Figure 5. The Spiral Curriculum Option



If the student does not improve from block to block in a practice sequence, the program generates a "teacher call," which tells the student to see his teacher before continuing. The teacher then tries to isolate and remedy the difficulty by analyzing the student's printout. Also, she can review the student's progress by examining his printout with him at the end of each day or week.

The Computer Related Instructional Systems Center offers consulting services to teachers who use the APTP program. Instruction includes use of the Teacher's Guide and supervised practice on the system as desired.

Provisions for Parent/Community Involvement

No special effort was made to involve parents or community in the use of APTP. However, the student does have his own printout available at the end of each of his interactions with the computer. Furthermore, his record book provides a means for him to know and report on his activities in mastering computational skills. The developers, therefore, report that the Arithmetic Proficiency Training Program ordinarily receives enthusiastic attention from parents because it provides them with a comprehensive and meaningful means of understanding what their child is doing and why. It is also possible for parents to serve as proctors, as mentioned under Teacher Activities.

Special Physical Facilities or Equipment

As indicated earlier, access to a computer is needed. It should be understood that the computer need not be in the school and that the computer will probably be used for administrative data processing such as payroll processing and class scheduling. Computer terminals are needed and a special room is recommended for these terminals, since experience with terminals in regular classrooms has thus far not been found satisfactory. In addition, if the computer is appreciably remote from the school, there is need for telephone connections between computer and terminals.

Recommended Assessment Techniques for Users

APTP deliberately blurs the usual distinction between test and practice, because of the developers' belief that student performance can be measured in much the same way in either a test situation or a practice situation. Thus the same kinds of problems are given in both test and practice modes; the

major distinctions between the test mode and the practice mode are: (1) in the practice mode, the student may be given several chances to get the correct answer for a given problem while in the test mode he has only one chance; (2) a test session on a given atomic skill is generally shorter than a practice session on that skill.

APTP thus provides a criterion-referenced assessment procedure keyed directly to each atomic skill in the hierarchy of skills in a molecule. In a school system making extensive use of criterion-referenced assessment, there would be little or no need for assessment techniques other than those provided by the record-keeping of APTP. The developers say, however, that most schools continue to evaluate programs of instruction on the basis of nationally standardized achievement tests and they feel that there is much value in carefully controlled evaluation plans with pre- and posttesting with such tests. In fact, they believe that such evaluation systems may be the only practical way by which school people will be able to decide whether there is significant value in computer-assisted instruction.

They warn, however, that their experience shows considerable danger that standardized achievement tests may lack adequate sensitivity at the lower end to reveal important gains made by students who are seriously below grade level. For example, many disadvantaged 7th-graders may be sadly lacking in mastery of the multiplication table but the tests usually administered at that grade level may be inadequate to reveal such lack or to show gains achieved by special programs.

ORIGINS

Key Personnel

The key personnel involved in the development of APTP contributed four types of expertise: management, subject matter and curriculum design, computer programming, and research and evaluation. Don Mitchell was director when the project began, although its conception and early planning occurred under John Lawrence, his predecessor and founder of the Computer Related Instructional Systems Center (CRIS). Noel Capettini became director in late 1968 and managed APTP from mid-development through completion of the product version. Bernard Jeltema is the present director and manages the continued development

and dissemination of APTP. Each of these directors was an SRA or IBM employee before becoming director of the Center. Their previous experiences involved computer related activities, teaching, and research and development.

Robert Fouch provided the subject matter and curriculum design expertise; he might be described as the principal architect of the program. He had had extensive experience in teaching and in teacher education and had been Director of Mathematics for SRA's Materials of Instruction Division before working on APTP.

Ed Foster and others supplied the computer programming skills. In addition to these computer skills, Foster's background included teaching experience.

Robert Rehula headed up the evaluation program for APTP. His background was in learning theory, and he had worked on the SRA Reading Laboratories. Thus, all key personnel were previously involved in work at SRA or IBM before working on the development of APTP.

Sources and Evolution of Ideas for Product

During Science Research Associates' early years, extending back to 1938, their focus was on testing and guidance. The first SRA Reading Laboratory was published in 1958. The single most important aspect, which came to influence development of many other instructional products (e.g., APTP), was that the Laboratory provided for individualization of instruction in the classroom. According to the developers, this reading program was so successful that "it just took off and flew." Because of this success SRA made the decision in 1959 to branch out into other subject matter areas. In 1959-60 people were hired to start efforts in social studies, mathematics, and science.

The social studies people got off to a quick start by designing materials very much in the same nature as the Reading Laboratory. Robert Fouch was brought in to develop similar programs in mathematics. He pointed out that even though the goals set for his department were very clear, the initial attempts at planning individualized materials in mathematics resulted in something that was physically unmanageable. Typically, they tried to cover too large an area. For several years, the department put most of its efforts into

production of math materials in more conventional media and format (e.g., the Greater Cleveland Mathematics Program.) Eventually, when they decided to narrow things down to just the computational aspects of elementary mathematics, they produced a Computational Skills Development Kit (CSDK) which was supplementary and very similar to the Reading Laboratories, both physically and structurally. Other individualized programs, each with a narrow scope, were also produced. CSDK had the virtues of providing individualized testing and placement into a linear sequence of practice work; there were provisions for quick (but not immediate) feedback to the student on his practice work. Fouch explained that CSDK was something of a minor breakthrough and that, although it was quite successful, it had many limitations resulting from the paper-and-ink medium used: provisions for testing were limited, feedback was not really immediate, the number of different practice problems was severely limited, the program was essentially a linear one, etc. CSDK and APTP (as later developed) might be said to have almost exactly the same goals; however, the limitations imposed by the paper-and-ink medium vanished when the potential of the computer was used in the development of APTP.

Funding for Product Development

Funding arrangements for development and testing of the Arithmetic Proficiency Training Program were entirely internal to IBM and Science Research Associates (which is a wholly owned subsidiary of IBM). Even in the Chicago field test (described later), the Chicago schools paid only for telephone costs; they did, of course, contribute greatly in terms of teacher cooperation but this was achieved without any special funding.

The cost of developing the Arithmetic Proficiency Training Program is proprietary information and could not be obtained. However, a rough estimate of the man-years of effort required to develop APTP would be about 20 man-years. At about $40,000 to $50,000 per man-year (including all support cost, especially costs of equipment), an estimate of IBM's investment would be a million dollars. Fouch insists, however, that such an estimate is not at all representative of present CAI development costs and that a program of like size could be developed for much less with today's "know-how."

PRODUCT DEVELOPMENT

Management and Organization

The Computer Related Instructional Systems Center of Science Research Associates is the developer of APTP. IBM purchased Science Research Associates in 1964 and made it a wholly owned subsidiary. SRA established the Center in late 1965 to explore computer applications in education (more specifically, in instruction, not in educational administration). For three years, the Center largely operated as a laboratory where a great deal of intermingling of persons and ideas took place. Interdisciplinary work was encouraged; there was much opportunity to experiment with various ways in which the computer could be used in instruction.

The Center has had four directors since it was started in 1965. Only the last two, Capettini and Jeltema, were significantly involved in APTP. However, before either Capettini or Jeltema became director, the Center had risen to its peak in terms of facilities and personnel (i.e., 35 people) and had already begun to decrease in size. At its zenith, the Center had an organizational structure consisting of a director and managers of curriculum design, evaluation, programming, and computer operations. Only three individuals are now employed by the Center; they are Fouch, Foster, and Jeltema.

The Center presently markets APTP, Computing Concepts in Mathematics, and APL/360 Reference Manual. Almost total emphasis is actually on APTP. According to Jeltema,

> There were several other things which were left in a prepublication form. In fact, there must be close to 25 or 30 monographs on applications of the computer at the senior high and college level in the fields of mathematics, chemistry, and physics.

Original Development Plan

Initial work on a formal development plan for APTP occurred in late 1967, with Mr. Fouch (transferred from SRA's Materials of Instruction Division) working closely with Arthur Siegel of IBM's Instructional Systems Development Division in San Jose, California. The broadest outlines of their planning were based on a change in direction of the Center from educational research with special purpose computing equipment such as the IBM 1500 System to

product development for standard hardware (specifically, the IBM System/360 and standard typewriter terminals).

Educationally, the computational skills of elementary arithmetic were selected as being a manageable piece of material--large enough to be of significant use to schools and yet small enough that development time would not be excessive. These computational skills were to be broken down into "molecules" and further broken down into smaller steps called atomic skills, and these atomic skills were to be organized in non-linear hierarchies. Criterion-referenced testing was to provide the basis for placement of the individual student and for advancement within the hierarchy. Individualized diagnosis, prescription, and monitoring of skill development was to be the aim.

Modifications in Original Development Plan

No significant changes were made in the original development plan. According to the developers, the program emerged pretty much as planned and pretty much as scheduled from 1968 on. Fouch explains that this occurred only because the original plan was very broad and flexible, details (such as precise scheduling) were filled in only when earlier stages were completed. While the various options (e.g., the "M" and "S" options) were not planned originally, they are considered extensions of original ideas rather than modifications in the original development plan.

Actual Procedures for Development

Development

The development of APTP was through the approach of the interdisciplinary team: a group of individuals, each with some highly developed specialty and each with at least some knowledge and/or experience in the areas of the other specialists. For example, nearly everyone on the project had at least a rudimentary ability in computer programming; a very large majority of personnel had a background of teaching experience; a variety of specialists had experience in development of diverse materials of instruction. The subject matter and curriculum design specialist, the computer programming specialists, the evaluation specialists, and the management specialist all had to interact

frequently in the development of APTP. Interaction and communication were greatly facilitated by these overlapping competencies.

Essential background to the development of APTP were several significant trends which had begun in the early 1960's and which were becoming common practice by this time. The third generation of computers was moving rapidly. The time-sharing system not only enabled computers to be programmed to operate and store work on several programs at a time but also to work on them in a sequence sufficiently rapid to give the user the impression that his work was being done at the same time as that of another user. This third generation of computers also brought along the connection of input-output devices to locations remote from the computer's actual processing unit. A person therefore didn't have to "own" a computer; he merely needed to buy or rent his own input-output device and rent time from the central processing unit. connecting with it over telephone lines.

Systems thinking had been introduced into the construction and use of curricular materials. Operant conditioning and immediate reinforcement theory were coming into their own. These effects were being brought together into curriculum construction as teaching programs. Thoughts were broken down into definite pieces which were presented for assimilation. Immediate comparisons of answers with desired answers were provided, and students were permitted to progress if right, and were sent back for additional work if wrong. The differentiation of skills into units raised interesting questions about the dependence of performance in one unit on mastery of prior units. This hierarchization of units became a central theoretical issue in the development of APTP. Programmed instruction finally brought the matter of criterion-referenced testing into the fore. It shifted testing from student-to-standard comparison. Additionally, the computer suggested the possibility that test questions could be given and scored even before the student was given his next question. This opened the possibility for "branching" testing, that is for testing which would take the person to places in the universe of content closer to where his skill level actually existed. The developers found in the universe of arithmetic proficiency content that it therefore became possible to introduce a placement and development sequence into the system programming of the Arithmetic Proficiency Training Program.

These trends, which were becoming common practice, greatly influenced the original development plan (noted above) that led to the actual development of APTP.

The developers, especially Fouch, had looked over many of the numerous applications of the computer in instruction. Computer-assisted instruction (CAI) was becoming quite popular at the time, but it was noted that many CAI programs were little more than linearly programmed textbooks inserted into a computer system, and that the only individualization that resulted was in slightly differing rates of going through the same sequence of material. Such programs seemed very unsatisfactory, both in terms of improved instructional effectiveness and cost-effectiveness. It was also noticed that most CAI programs made only limited use of the potential of the computer (particularly for branching and decision-making) and this was in part due to seeming constraints of special-purpose CAI languages.

It was therefore decided to start with educational objectives (in general, maximum individualization, immediate reinforcement, high motivation) and to find ways to make the computer do the things needed to achieve those objectives, even though they might not have been done in other CAI efforts. The choice of a computer language became very important at this point; the language chosen was APL/360, a language that had already been used with considerable expertise by CRIS programmers. APL is a general purpose, high level interactive computing language. The "high level" nature of APL means that it is very easy for a programmer to write programs of considerable power quickly, to debug and to revise them quickly; this is in contrast to lower level languages which may require the programmer to spend large amounts of time on minute technical details. The developers thus gained the advantage of being able to try out new ideas and sophisticated techniques very quickly, and also to make quick revisions. It should be mentioned that, on the other side of the balance sheet, APL has the disadvantage of requiring a rather large computer and, as a consequence of this, APTP was eventually reprogrammed in Coursewriter III, a language demanding much greater effort from programmers but requiring an appreciably smaller computer.

The developers see the development of APTP as occurring in three phases: (I) informal tryout; (II) development and testing of the APL version; (III) reprogramming in Coursewriter III (the final product version). Together, the

three phases constituted a sort of evolutionary process. In Phase I, segments of the program with many different variations were tried out with students who came into the Center voluntarily after their regular school hours. Many ideas were discarded as a result of this and many new ideas came out of watching these students and talking with them about their reactions.

Phase II began in the spring of 1968 and consisted of the preparation of the APL version to be tested in the Chicago Public Schools during the school year 1968-69. Still taking advantage of the fast revision potential of APL, many changes were made during the testing process as the feedback from student use would show inadequacies in the first draft and would produce new ideas for improvement.

Phase III began in early 1969 and considerably overlapped Phase II. When satisfaction had been attained about the early segments of the APL version, reprogramming of these segments in Coursewriter III would begin while testing of later segments of the APL version continued. Although it is largely true that the completed APL version might be said to constitute the detailed specifications for the Coursewriter version and that the two versions were intended to be indistinguishable to the teacher or student, it is also true that further modifications and improvements were built into the program during Phase III. These were largely enhancements to the program (e.g., the "M" and "S" options), things which the Chicago use had shown to be desirable although not necessary.

In addition to the formative evaluation of the program in the Chicago Public Schools, the Computer Related Instructional Systems Center made arrangements with the Memphis, Tennessee Public School System to field test the program. This is described under Summative Evaluation.

Since the Arithmetic Proficiency Training Program is essentially a computer program licensed for operation on an IBM System 360, the program had to pass IBM's systems standard test before it could be released and licensed. This is a technical test to insure that the program will operate according to specifications when leased to a user. This is a standard policy within IBM and therefore within Science Research Associates, an IBM subsidiary. The program was subjected to these tests during 1969, in conjunction with the IBM Service Bureau Corporation and an IBM group in Poughkeepsie, New York. The program met standards with only slight modification to compensate for too high density coding in a few places in the program.

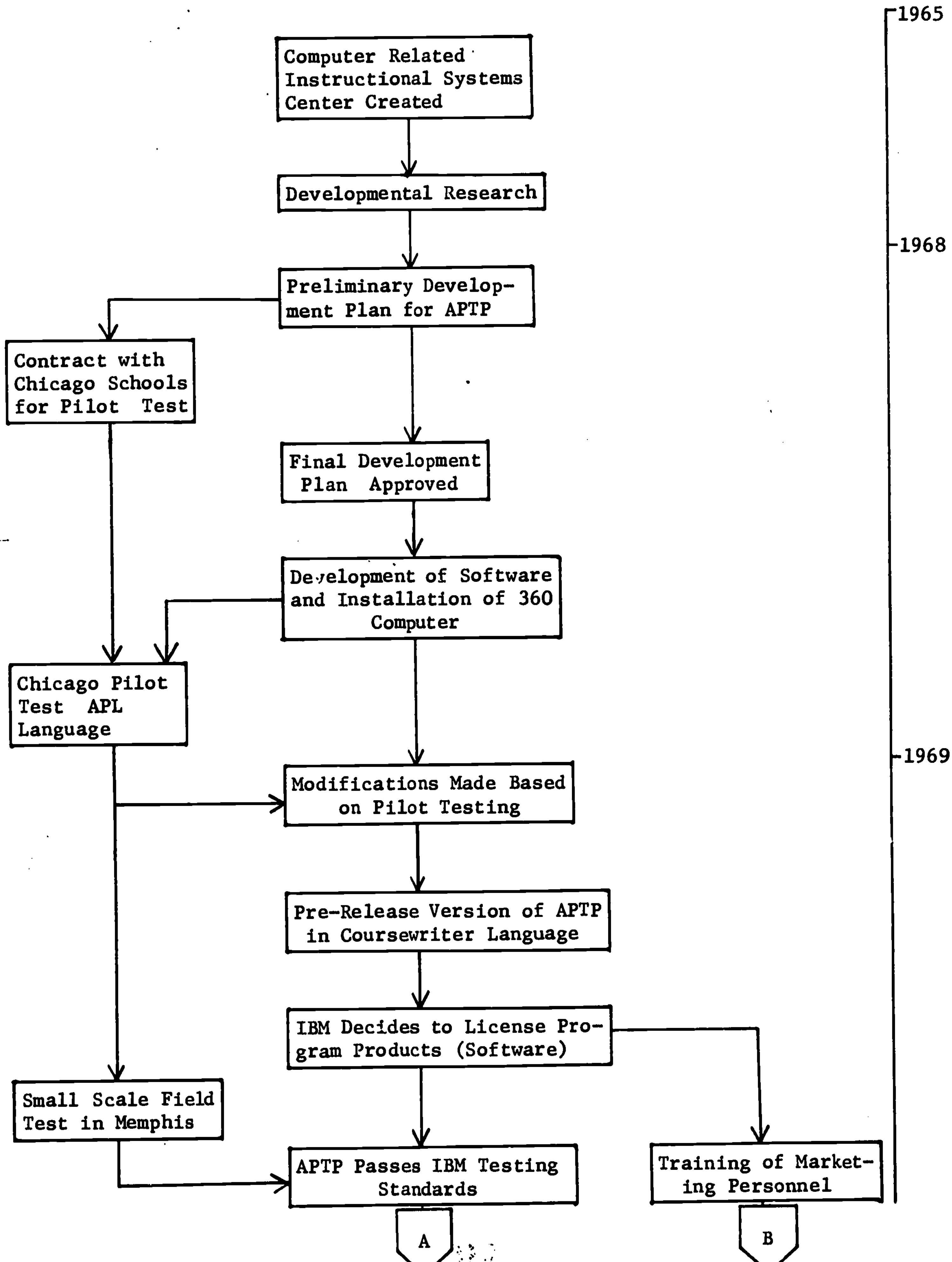
See Figure 6, the Major Event Flow Chart, for the main activities leading up to, including, and following the actual development of APTP. As indicated in the chart, development took only about a year and progressed rather rapidly once the basic concept of APTP was clear to the developers.

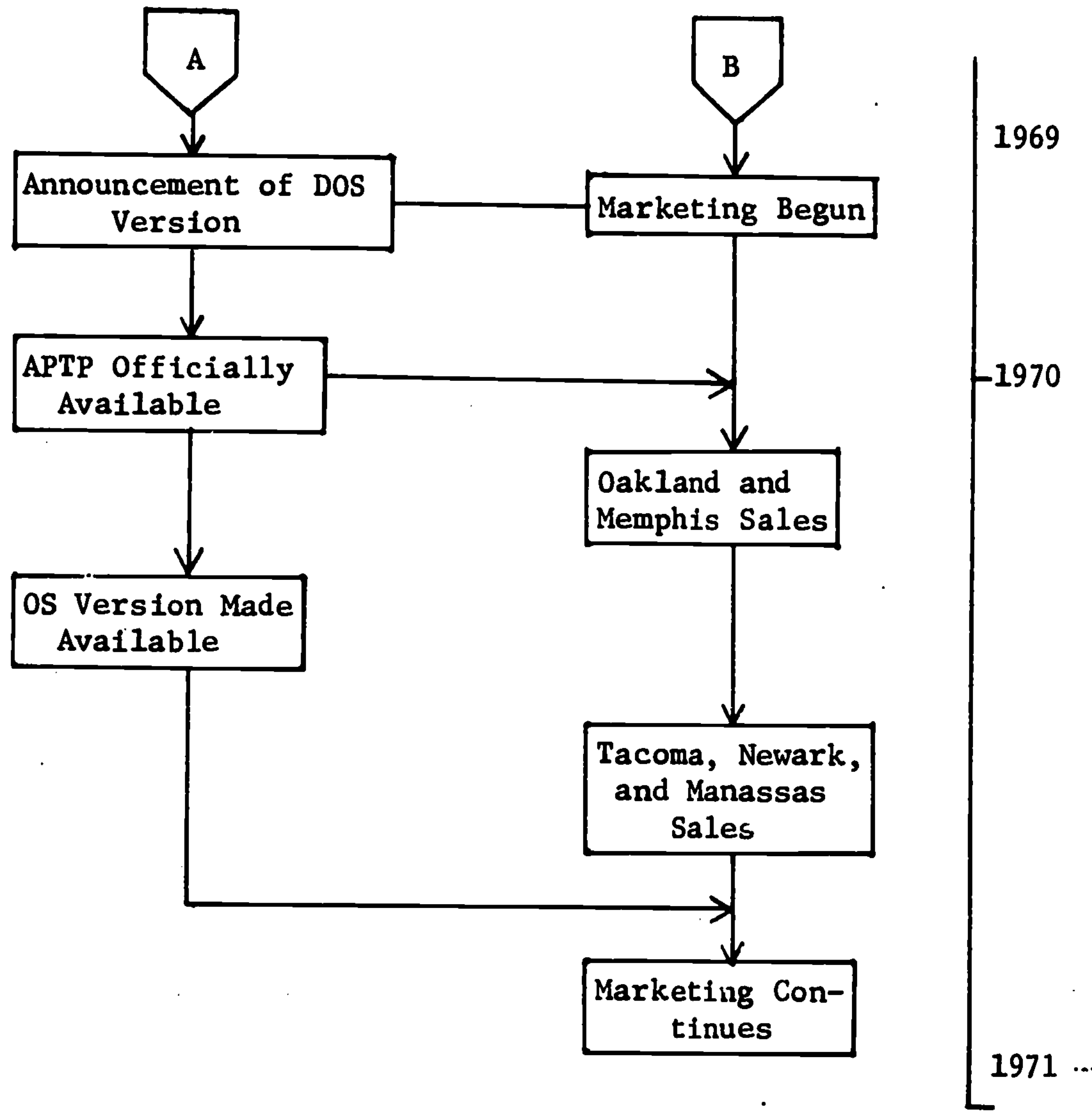
Formative Evaluation

Beginning in October 1968, the Computer Related Instructional Systems Center and the Chicago Public Schools entered upon a field trial of the Arithmetic Proficiency Training Program in grades 6, 7, and 8. Two hundred ninety-three students in the program who were attending one of the eight schools were initially included in the sample. Six of the eight schools sampled were from the inner-city of Chicago. Forty-two percent of the students were black, 47% white, and 11% other (primarily Spanish-speaking). Attrition occurred but substitution of students was arranged when necessary and possible. Two hundred twenty-six students participated fairly regularly throughout the program's trial. Two typewriter terminals were installed in each school and connected by telephone lines to a remotely located time-sharing computer system. The program, the terminals, and the computer time were all supplied by the Computer Related Instructional Systems Center as was the evaluation staff and report. Students were scheduled daily for 20-minute sessions with the program. In the course of the seven-month study, daily performance of the students was recorded; subjective opinions of students, teachers, administrators, and parents were assembled; and final achievement results were obtained for the involved students and a comparison group.

An example of the individualization achieved by the program is in the molecule on subtraction of whole numbers. One student worked 16 problems in a period of 9 minutes, 40 seconds, to demonstrate his mastery of the highest level atomic skill in the molecule. The low end of the range was held by another student who worked 1,332 problems in a period of 15 hours, 40 minutes, to demonstrate the same level of skill mastery. Records like these were readily secured from the program since student reports were generated at the conclusion of each session. Assembly and analysis of these reports provided specific indication of the track which the program and the student jointly took for the student to reach mastery in each of the molecules assigned or attempted. Such records demonstrated that the majority of participating students did make significant progress.

Figure 6. Major Event Flow Chart




A
B
1969
Announcement of DOS Version
Marketing Begun
APTP Officially Available
1970
Oakland and Memphis Sales
OS Version Made Available
Tacoma, Newark, and Manassas Sales
Marketing Continues
1971

32

Opinion data were secured in May 1969 from students, teachers, administrators, and parents. A questionnaire and an interview were used. Findings included:

- High degree of sustained motivation in students--In May, 94% of the students reported that they liked the program; 75% reported they liked it more at the end of the year than they did at first; teachers unanimously reported that the students were more enthusiastic.

- Positive influence on student performance in arithmetic--82% of the students reported that the program helped with their work in their mathematics classes; 81% reported that they liked arithmetic in general more than before and that it was more interesting to them; 79% of the students reported that they worked arithmetic problems more carefully and faster than they did before participating in the program; 82% of the teachers noted increased student interest in mathematics and improved student performance in regular mathematics classes.

- Immediate feedback creates increased student interest--88% of the students reported that they were able to tell immediately the quality of their daily work at the terminal; students liked immediate feedback, particularly in the case of correct responses--96% of the students reported that they liked to be told they were correct; 64% reported that they liked to know immediately when they were wrong.

- Observation of student behavior shows desire to participate in A.P.T.P--Observation indicated that students tended to arrive early for A.P.T.P sessions, and there was no evidence of cutting sessions though students were "on their honor" to go to the terminal room. 90% of the principals and 100% of the teachers reporting stated that there was little or no disruption of classrooms or hallways due to student participation in A.P.T.P.; many students not in the program asked to be included.

- Parents' reactions favorable--Teachers and principals reported that the attitude of parents they came into contact with was generally favorable to the program; many parents whose children were not in the program requested that they be included whenever an opportunity presented itself.

- Teachers' attitudes generally favorable--Teachers involved in the program unanimously agreed that there was no disruption of normal classroom activity due to children participating in A.P.T.P.; they also unanimously agreed that they would like the opportunity of using other CAI materials, thus seemingly indicating that their initial experience with a CAI program was a good one; also, 77% of the teachers reporting felt that all students would benefit from using A.P.T.P.

(Rehula, et al 1969)

Students were pretested (October 1968) and posttested (May 1969) on the Computation Subtest of the SRA Achievement Series and on another test especially prepared for the educational objectives of the Arithmetic Proficiency Training Program. On the standardized Computation Subtest, the adjusted mean scores for the program group differed significantly from that of the comparison group in the sixth grade subjects, but not in the seventh and eighth grade subjects. The proportion of whole number problems contained in the Computation Subtest diminishes from grade six through grade eight; and since the majority of students using the program practiced for the most part in its whole number section (only 35% progressed beyond whole numbers), the effect of practice from the program might not have shown up well on the Computation Subtest. In the sixth grade group, in particular, results also indicated that the program took its students from below national norms in the beginning to well above them by the end. The comparison group remained below these norms in both testings. On the specially constructed test, the program group did significantly better on its facts section than did the comparison group. The difference did not hold up in the total computation score on this special test. However, when computation with whole numbers was separated from the total computation score, the difference between the program and comparison groups was not significant once again.

Although the pilot test of the Arithmetic Proficiency Training Program in the Chicago Public Schools yielded the overall data summarized above, a specific purpose of the pilot test was to gain information on the operating characteristics of the program itself. A number of observations on those initial operating characteristics were especially informative for understanding the problems involved in automating an interaction between student and material in the computational area.

Equipment down time. Out of a possible 745 hours of operating time, the computer was down 35 hours, 43 minutes. This was about 5% down time. Out of 1,625 usage hours at the 16 terminals, 450, or 5.2%, proved unavailable for use when wanted. These data are for the APL version; the developers state that later data for the Coursewriter version has indicated considerably improved reliability.

Molecule size. The time needed for students to complete a whole number molecule was underestimated. Particular problems were encountered with the

difficulty level of upper-numbered skills in the whole number molecules. These problems were temporarily solved by placing students on another molecule while the number of skills in each of the molecules was then shortened to prevent similar difficulties again.

Placement phase. A small test was made to determine if students could pass the test which the program skips over as it works to get the student placed in the molecule. Results were affirmative in this trial. Placement worked.

Test mode. It was found that the diagnostic test accurately predicted that a student did not need practice when he passed the test. However, the necessity for practice when a student failed the diagnostic test did not emerge as clearly. It was hypothesized that the work on problems in the test mode actually served as practice which carried over into the developmental aspects of the program which occur some time after a diagnostic test is failed.

Practice mode. Eighty percent accurate responses seemed a reasonable criterion of expected accomplishment. Typically, students passing a skill in test mode passed the experimentally arranged subsequent practice sessions on that skill within one problem block.

Developmental phase. Developmental work in the program does result in generalization to problem solving in the future. Results of this assumption were reported earlier on the standardized and special tests.

Timing. Students liked the timing competition which the program arranges. Nevertheless the accuracy objectives of the program proved to be met more readily than the timing objectives. The timing objectives were therefore considerably modified after this field experience. But there were still questions which needed to be addressed by studying the relationship between accuracy and speed in the acquisition of computational skill.

Keyboard training. The molecule on keyboard training seemed to work effectively. However, the keyboard introduced difficulty in program operation in early sessions for a student, particularly his first session. It took a second or third session for students to become familiar with the keyboard and problem formats and responses.

Readibility of program messages in whole numbers. Ninety percent of the vocabulary of the program fits into the Thorndike-Lorge estimation of grade 5

vocabulary. Reading level for messages as entire articles was grade 4.8. The grade level of messages, therefore, had to be lowered in several regards to set the lower grade levels for which the program is recommended.

The terminal. The typewriter in general proved an effective medium for program presentation to the student and for student response. However, a number of needed engineering changes were unearthed during the course of the pilot testing. The plastic shield under the typeball and the roller bar were necessary for operation, but disconcerting during problem solving when the sheet had to be closely watched for alignment. Difficulties were experienced with problem alignment and with the needed double back spacing of the typewriter to achieve column alignments in solving a problem from right to left. Some reprogramming had to be done in both instances. The height and angle of the terminal also caused difficulty for some students. An adjustable chair proved necessary. Two-part paper caused difficulty because paper shifted. One-part paper worked better. Some need for reconsidering the typewriter was advanced but the advantages were still felt to be sufficient to keep it in use.

The computer and the program. Time for the computer to respond to a student's answer to a problem proved to be a considerable factor in maintaining student interest. It was recommended that this should be kept to a maximum of five seconds. (The developers say that these excessive computer response times were a result of inefficient programming of the APL version and of an overly heavy load on the computer. With the Coursewriter version, the goal has been a maximum response time of 2 seconds and this has generally been achieved. Only 2½% of the computer down time was directly attributable to the program. This percentage was called "tolerable," but it obviously called for understanding from users and capable operators at the central processing unit of the program.

A number of changes were made in the Arithmetic Proficiency Training Program as a result of its initial field trial in the Chicago Public Schools. Reported modifications included:

1. The keyboard program was modified to include further instruction.
2. Automatic positioning of the typeball to its desired first position was provided for each problem to be solved.
3. Programming was included to guard against a student having to return to the very beginning of his session each day if

the system "goes down" during his session. Programming was instituted which permitted him to pick up at some intermediate point from the beginning when the system started to function again.

4. Several new options were made available to the teacher or supervisor of the program. These enhancements were achieved by making use of certain aspects of the Coursewriter language--things that were not feasible in the APL version.

5. Messages to the student were shortened to make the program more readable.

6. A worked out example was inserted at the beginning of each new skill in order to show the student the format of the answer in the skill.

7. Several procedures formerly performed "by hand" were automated. These included the movement of a student from one molecule to the next.

SUMMATIVE EVALUATION

The Computer Related Instructional Systems Center was in conversation with the Memphis Community Learning Laboratory during the same time that its first formative evaluation with the Chicago Public Schools was in progress. Out of these conversations came the first user operated trial of the Arithmetic Proficiency Training Program.

Prior to the Memphis field test, a first draft of the reprogramming of the Arithmetic Proficiency Training Program into the Coursewriter III language had been completed. Coursewriter III had then been accepted as the IBM computer language for computer-assisted instruction; this reprogramming also included subroutines programmed in Assembly Language. This combination of languages gave the program greater versatility by providing additional teacher directed functions which were hard to permit in APL, the language in which the program was originally written. However, using both languages for the program gave the entire program greater flexibility and power than would have been available in either language alone.

Lea W. Joyner, CAI Coordinator in Memphis, and Longno A. Cooke, Jr., Director of the Memphis Community Learning Laboratory, were primarily responsible for the conduct and report of the Memphis field test of the Arithmetic Proficiency Training Program. As will be noted, this field test was a small scale effort.

The experimental group to which the Arithmetic Proficiency Training Program was given in this 1969-70 field test consisted of 15 sixth grade students. The experimental group was matched by 15 other sixth grade pupils. The Thorndike-Lorge IQ Score as of November 1968 and the April 1969 Arithmetic Computation Score on the Metropolitan Achievement Test were used simultaneously for this matching. The matching also resulted in acceptance of the hypothesis that the experimental and control groups did not differ in their Arithmetic Problem Solving and Concepts scores on the April 1969 Metropolitan Achievement Test.

On a different form of the Metropolitan Achievement Test administered to both groups in April 1970, the experimental group performed significantly better than the control group as indicated by their Computations, Problem Solving, and Concepts scores. It did appear that the 16 to 24 hours which the experimental group had on the Arithmetic Proficiency Training Program resulted in achievement gains. No significant correlations were found relating amount of growth to either IQ or length of time on the program.

DIFFUSION

Agency Participation

Initially, SRA staff associates were given primary responsibility for diffusion activities and marketing. Recently, all aspects of diffusion and marketing have become concentrated in the Computer Related Instructional Systems Center. Marketing APTP is a major function of the Center at SRA.

Diffusion Strategy

The strategy was essentially the same as that used by SRA for its other products: promotion by SRA's sales force of staff associates, by direct mailings, by catalog listings, etc. However, this was complicated by two factors: the school's need for computer equipment capable of running CAI programs (which they seldom had prior to their interest in APTP), and the need of marketing personnel for a great deal of technical knowledge about computers. APTP was sold only by SRA, but it ran only on IBM equipment which was not sold (or leased) by SRA.

A further complication resulted from IBM's long-standing practice of providing services and programs with the sale or lease of its equipment. However, in June 1969, IBM announced its decision to price services and programs separately from equipment. This supplied a simple solution to SRA's problem of following general IBM practices and, at the same time, of gaining revenue from CAI programs. It was therefore decided to price APTP in a fashion parallel to IBM's new practices for leasing program products.

Actual Diffusion Efforts

The sale of the Arithmetic Proficiency Training Program represented a marketing "first" for Science Research Associates. SRA was going out to sell materials involving the computer as a medium. SRA therefore put a lot of attention and effort into marketing the Arithmetic Proficiency Training Program. Internal announcement of the program's availability was scheduled for mid-September 1969. A selected group of SRA's staff associates for selling its materials to elementary and high schools was brought into SRA's Chicago home office for a five-day conference in August 1969. Since most of these staff associates were unfamiliar with computers, they were given three days of training about the computer and its programming. Materials used included Computing Concepts in Mathematics, thus also familiarizing them with another product of the Computer Related Instructional Systems Center. The last two days of this conference were spent training the staff associates specifically about APTP. The Arithmetic Proficiency Training Program was unveiled a month later. Sales people were urged to sell it.

Public announcement of the forthcoming availability of the Arithmetic Proficiency Training Program signalled a second step in the program's marketing effort. Personnel for the Computer Related Instructional Systems Center hit the "sawdust trail." Demonstrations of the Arithmetic Proficiency Training Program were arranged in several major cities. SRA staff associates were host to their contacts in these cities. The Center came in and made its "pitch." Problems were encountered in securing terminals. Jeltema reported that there just wasn't any effective substitute for the "hands on" experience with the Arithmetic Proficiency Training Program. When an interested customer allows himself to interact with the program, the program begins selling itself. Until

that time the program is an interesting "toy" of our technological age. Jeltema noted:

> As things evolved, we found that one of the best ways to demonstrate is to see it in operation in a school. Another excellent way is to get a terminal and capture a child who's had no previous experience but gets about five minutes of how to do it. It's amazing how well they operate even with that kind of background. Still another effective way is to have the person sit down and do it himself. The least effective way is either to do it for him or talk about it without the terminal.

At the present time the Center is experimenting with videotape presentations. The Center is also beginning to push its recent incorporation into the program, the spiral curriculum.

A brochure explaining the system is available and distributed widely--"in the thousands." The brochure has a return postcard by which a person expresses interest and requests further help. These postcards are followed up in various ways.

In the beginning, interest was passed along to SRA staff associates who were entrusted with following it up. Staff associates sell on a commission basis. Sale of the Arithmetic Proficiency Training Program was put on this commission basis at first. However, it quickly became apparent that the installation of the program is complex and that sale is neither easy nor frequent. For instance, installation includes: training the teachers; training the proctors; acting as educational counselors; helping the buyer design and experiment for evaluation; and being present when children operate terminals for the first time. In addition, a school system has to have or rent computing facilities and terminals. All this means that the school has to be quite interested in the program before it is willing to take on the program's added effort and cost in the school's mathematics instruction. In addition, the Center has been plagued by the schoolman's need for proof "that it works" before he feels able to go to his school board and taxpayers with a request for the needed funds and support. As is indicated above, field trials do indicate that the Arithmetic Proficiency Training Program "works." However, it is also evident that how well and with whom it works has not been convincingly demonstrated. The logic of the program's operation has proven insufficient to sell widely.

This experience led the Computer Related Instructional Systems Center to withdraw marketing of the Arithmetic Proficiency Training Program from general responsibility of SRA staff associates. The result is that marketing is now concentrated in the Center itself: "We met our objectives in terms of sales, and obviously they were modest. We didn't expect it to get started quickly. We do expect it to grow."

Product Characteristics and Other Factors Affecting Diffusion

APTP was designed to be a supplementary mathematics program that would be compatible with most school practices. The computer programs that make up the software can be leased as a complete unit. Teacher training is provided, but only through the teacher's guide and the consulting services of SRA. Start up costs, as noted earlier, are often considered expensive given the economic conditions of today, the need for computer facilities, and the fact that APTP is a supplementary program.

ADOPTION

Extent of Product Use

Extent of use of a CAI program is viewed by the developers as a difficult thing to measure by any single number such as number of students (since this does not show anything about how much use was made by each student). They favor stating the number of terminals dedicated to CAI use, but admit that this is not satisfactory either since it fails to show whether a terminal was used for one hour or for 100 hours each week.

In the four school systems using the program after the formative evaluation in Chicago, the following numbers of terminals were installed:

Oakland, Calif.	(Spring, 1970)	35
Memphis, Tenn.	(1969-70)	6
	(1970-71)	16
Tacoma, Wash.	(1971)	15
Newark, N. J.	(1971)	15

APTP may be used in sessions of any length specified by the teacher; however, the developers do not recommend sessions of less than 10 minutes. A better picture of the extent of use may be acquired by imagining sessions

averaging 15 minutes each, during a six-hour school day. Thus, each terminal can serve 24 students per day. This number can be increased considerably by extending the use of the program to after-school hours, to adult education in evening hours and on Saturdays, etc. The situation is further complicated by possible variations in scheduling individual students: each student might be scheduled for a session every day or every other day or two days a week; and this scheduling might be for a whole school year, for six weeks, or until the student has demonstrated a certain achievement level.

Memphis, Tennessee represented a sale which was a continuation of its field involvement. Newark and Tacoma represented new sales. However, the first new sale was to Oakland, California schools during spring 1970. The Oakland schools came in fast because they had the available computer facilities and money to help in the education of disadvantaged pupils. However, they did not continue to buy when initial supplementary funds were exhausted.

APTP was also recently used by an IBM manufacturing plant in Manassas, Virginia. The program was used initially in the Manassas plant for a small experiment in training a group of new-hires in a three-month training program in which the plant participated under the National Alliance of Businessmen. The Manassas experience led the plant's management to decide to include the program in their ongoing voluntary employee education efforts. Several IBM sites are expecting to use the program for their employee training programs.

Installation Procedures

APTP requires a computer and terminals, and the necessary room organization that allows the student to work at the terminal when supplementary mathematics work is scheduled. Some public relations effort prior to adoption is advisable and administrative support is needed. The latest options allow the teacher to modify the program to meet her needs. Teacher training is important. The developers feel that CAI is a new tool for use in the instructional process and that, like any other tool, it will produce valuable results only when used by people who understand it and who have become skilled in its uses. CAI is not a tool that can really run all by itself nor is it so ideally designed as to be incapable of misuse. Until some future time when schools of education regularly give courses in the use of CAI, the individual school users of CAI will need to supply the needed special training, probably with the aid of the

development group. As noted earlier, and below (see Table 1), in the suggested organization of personnel, there are extra staff requirements.

SRA has prepared a suggested organization of personnel for schools that adopt APTP. They have developed a chart that lists the major tasks to be performed and indicates with an X the person best suited to perform each task. Where more than one X appears, anyone of the persons indicated may suitably perform the task. See Table 1. As described in the chart, the systems supervisor is the overall coordinator of the program. The proctor monitors the terminal, handles any problems having to do with the functioning of the program or equipment, and takes responsibility for the students using the terminal room. The data processing manager is responsible for the functioning of the computer and for maintenance of the machine-readable materials. The developers point out that this is only one of many possible organizational charts. In some schools, it may be more advantageous to assign tasks to persons other than those indicated in the chart. The method of organization a school chooses will depend on the talents and availability of its personnel.

FUTURE OF THE PRODUCT

The Arithmetic Proficiency Training Program emerged as one of three present products of a developmental effort organized in late 1965 within Science Research Associates to develop computer related instructional materials. Mathematics programs are two of the Center's three presently available products. An APL manual is the third. In actuality, almost total emphasis in the Center is on APTP.

The effectiveness of APTP was suggested, but not convincingly demonstrated, in several field trials. Present customers find the product useful. IBM educational programs are beginning to use the program, suggesting that it is cost effective as well. But still a "million dollar" product is being used by no more than eight schools. There is no obvious single answer to why this is so, but some of the factors noted under Factors Affecting Diffusion suggest possible reasons. APTP requires a central processing unit of the size of the IBM System/360 Model 30. The program requires installation, operation, and servicing terminals. The program requires that teachers adapt themselves and their instruction. The program requires a proctor. Thus, there are the usual

Table 1. Suggested Organization of Personnel

Task	Proctor	Teacher	Computer Operator	Data Processing Manager	APTP Systems Supervisor
Select students		X			
Schedule students		X			X
Give students a brief introduction to the pedagogy of the program		X			
Determine modification of the program for individual students		X			X
Give students needed arithmetic instruction after a teacher call		X			
Determine modifications of the program that are necessary for individual students when they receive a teacher call		X			
Enter program modifications into the computer	X				
Monitor terminals	X				
Keep all necessary external APTP records	X				
File and maintain all necessary student material and equipment	X				
Order supplies	X				
Call repair service for terminals or data-phones	X				
Register students			X	X	X
Monitor computer			X		
Give students brief introduction to the use of the terminal		X			
Answer proctor questions pertaining to the terminal or computer				X	X
Obtain answers to questions asked by the proctor related to other than terminal or computer					X
Authorize repair service calls				X	X
Serve as liaison between proctor and other staff members involved in the use of APTP					X
Maintain machine readable materials			X	X	

obstacles to school improvement; namely, added equipment, noise, nuisance, understanding, and personnel. But the Arithmetic Proficiency Training Program suffers an additional and very large obstacle as well. It takes a time-shared computer to service the interactions of the program. Not many schools command computers or their time. Thus the Arithmetic Proficiency Training Program suffers as a product without a delivery network. At the same time, sale or rental of computers in schools suffers from interest in a new delivery system which lacks a sufficient quantity of sensible materials like the Arithmetic Proficiency Training Program. It remains to be seen how SRA and IBM will jointly approach its continuing problem of developing more educational software that will be adopted by schools.

CRITICAL DECISIONS

The following events are a good approximation of crucial decisions which were made in the four-year history of the Arithmetic Proficiency Training Program. For each decision point, the following types of information were usually described: the decision that had to be made, the alternatives available, the alternative chosen, the forces leading up to choosing a particular alternative, and the consequences resulting from choosing an alternative.

Although an attempt has been made to present the critical decisions or turning points in chronological order, it must be clearly pointed out that these decisions were not usually made at one point in time, nor did they necessarily lead to the next decision presented in the sequence. Many of the critical decisions led to consequences that affected all subsequent decision-making processes in some important way.

Decision 1: To Analyze Skills into Sub-Skills and to Organize These Skills into Hierarchies

Once the developers had narrowed their forces to arithmetic computation, they had to decide how to organize the computational skills. They knew students needed to start near their present level of competency and work at their own level and at their own pace. On the basis of this understanding, the developers decided to analyze the computational skills into sub-skills and then to organize these skills into hierarchies of prerequisites. Thus the student could start

near his present level of competency and proceed by small steps to mastery of the most complex skills that he needs. This decision was very much in line with the trends of the time.

Decision 2: To Use the Computer to Test, Place and Develop the Skills in Students.

The Computer Related Instructional Systems Center was given the assignment of figuring out how the computer could best be used to individualize instruction in elementary arithmetic. While the decision to use the computer was, thus, partly determined, the developers realized that the computer could offer the student individualization in both diagnosis and practice. At the same time, it could allow the teacher to direct the student's practice without having to supervise it. The computer could allow flexibility in decision making, through branching programs and through personalized diagnosis and immediate feedback. While this decision to use the computer facilitated the incorporation of these options considered critical, the decision may also have limited the extent of one of the products because of the economic considerations.

Decision 3: To Have the Developers Work Closely Together

The developers decided quite early that the specialists in each area (e.g., curriculum design, or computer programming) would have to work very closely together. The developers observed that typically the computer programmers are off by themselves while the other developers are involved in comprehensive planning; what usually results is a series of compromises forced upon these planners by the computer programmers. To prevent unnecessary compromises and to benefit from all the potentials of the computer, frequent interaction was a general policy that was appreciated by all the specialists. This decision facilitated development and helped the developers to tap many of the resources of the computer.

Decision 4: To Pilot Test the Program

Once the program was in operating condition, the developers decided that they needed information on how it would work in a real school situation. The developers figured that information on the operating characteristics of the

program would help solve some of the unrecognized problems involved in automating an interaction between student and material in the computational area. Their pilot test provided information on such characteristics as: equipment down time, molecule size, timing, placement, and student-terminal interaction. As a result of the pilot test, a number of critical changes were made in the program. Such changes as the incorporation of the Coursewriter Language enabled new options, like the spiral curriculum, to be offered.

REFERENCES

Rehula, R. J., Beckman, D., Pakin, S., & Stith, C. Field test report of the Arithmetic Proficiency Training Program prepared for the Chicago Board of Education by Science Research Associates. Chicago: Science Research Associates, Inc., 1969.

Staff of the SRA Computer Related Instructional Systems Center. A.P.T.P. Teacher's Guide. Chicago: SRA, 1969.

APPENDIX A

LIST OF PRODUCTS AND DEVELOPERS

The following is a list of products for which Product Development Reports have been prepared.

Arithmetic Proficiency Training Program (APTP)
Developer: Science Research Associates, Inc.

The Creative Learning Group Drug Education Program
Developer: The Creative Learning Group
Cambridge, Massachusetts

The Cluster Concept Program
Developer: The University of Maryland,
Industrial Education Department

Developmental Economic Education Program (DEEP)
Developer: Joint Council on Economic Education

Distar Instructional System
Developer: Siegfried Engelmann & Associates

Facilitating Inquiry in the Classroom
Developer: Northwest Regional Educational Laboratory

First Year Communication Skills Program
Developer: Southwest Regional Laboratory for
Educational Research & Development

The Frostig Program for Perceptual-Motor Development
Developer: The Marianne Frostig Center of Educational Therapy

Hawaii English Program
Developer: The Hawaii State Department of Education
and The University of Hawaii

Holt Social Studies Curriculum
Developer: Carnegie Social Studies Curriculum Development Center,
Carnegie-Mellon University

Individually Prescribed Instruction--Mathematics (IPI--Math)
Developer: Learning Research and Development Center,
University of Pittsburgh

Intermediate Science Curriculum Study
Developer: The Florida State University,
Intermediate Science Curriculum Study Project

MATCH--Materials and Activities for Teachers and Children
Developer: The Children's Museum
Boston, Massachusetts

Program for Learning in Accordance With Needs (PLAN)
Developer: American Institutes for Research and
Westinghouse Learning Corporation

Science--A Process Approach
Developer: American Association for the Advancement of Science

Science Curriculum Improvement Study
Developer: Science Curriculum Improvement Study Project
University of California, Berkeley

Sesame Street
Developer: Children's Television Workshop

The Sullivan Reading Program
Developer: Sullivan Associates
Menlo Park, California

The Taba Social Studies Curriculum
Developer: The Taba Social Studies Curriculum Project
San Francisco State College

The Talking Typewriter or
The Edison Responsive Environment Learning System
Developer: Thomas A. Edison Laboratory,
a Subsidiary of McGraw Edison Company

Variable Modular Scheduling Via Computer
Developer: Stanford University and
Educational Coordinates, Inc.